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DESIGN AND DEVELOPMENT OF A SOLAR/ELECTRIC POWERED HYBRID VEHICLE WITH TIL TANGLE ADJUSTMENT

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ABSTRACT

This paper explains the design and development of a solar power/electric vehicle with tilt angle adjustment. Here we design a vehicle which is powered by solar and also chargeable with an adapter with AC current. The solar plates are adjustable for tilt. The radiation of the sun varies on earth when the earth rotates it. The maximum power will be delivered by the solar PV cells when it is in normal to the sun. So tilting the angle of the solar collectors to keep it in normal to the sun different mathematical and automatic process is carried out around the globe. Our research implements the mathematical model for calculating tilt angle for the collector nodes starts from the longitude of 74.35 to 93.95, the latitude of 37.05 to 6.75 for collector nodes for India for 12 months of time. The designed vehicle is tested at an different latitude. The results prove that each month the angle of the collectors changes with the latitude respective of each month for absorbing maximum energy.

***KEYWORDS**: Solar Energy, Tilting Angle & Mathematical Model*

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Original Article

INTRODUCTION

This report proposes a Solar Electric Powered Hybrid Vehicle (SEPHV) system which solves the major problems of fuel and pollution. An electric vehicle usually uses a battery which has been charged by the external electrical power supply. All recent electric vehicles present a drive on AC power supplied motor. An inverter set is required to be connected to the battery through which AC power is converted to DC power. During this conversion many losses take place and also the maintenance cost of the AC System is very high. The proposed topology has the most feasible solar/electric power generation system mounted on the vehicle to charge the battery during all durations. With a view to providing ignited us to develop this “Solar/Electric Powered Hybrid Vehicle” [SEPHV]. This multi-charging vehicle can charge itself from both solar and electric power. Solar vehicles depend on PV cells to convert sunlight into electricity to drive the permanent magnet DC motors. Unlike solar thermal energy which converts solar energy to heat, PV cells directly convert sunlight into electricity. According to recent surveys, the fossil fuels are depleting at a fast rate where in and around 50 years the whole fossil fuel in the world must be completely depleted. Therefore it is the need of the time to make a new exploration of natural resources of energy and power among the natural resources

Available sunlight is the most promising one. Sunlight is considered to be a source of energy which is implemented in various day to day applications. The Solar/Electric Powered Hybrid Vehicle contains the solar panel, Permanent Magnet DC motor, batteries, steering, controller, accelerator, wheels, and chassis. One of the

most important points is the construction of the vehicle is that it is closely related to the chassis design, with the purpose of achieving a structural optimized work. So, in order to make the vehicle move under low power consumption and the redesign of chassis has to be done. The design was conceived from point of view of a high efficiency, lightweight and stable transport with reduced costs and zero emission in its operation and in the obtaining of the energy.

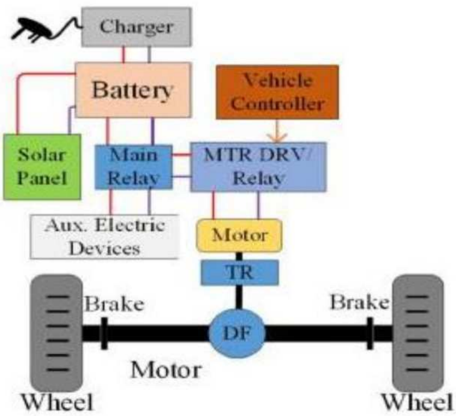

Figure 1: Basic Block Diagram of Solar Powered Electrical Vehicle

The radiation of the sun varies on earth when the earth rotates it. The maximum power will be delivered by the solar PV cells when it is in vertical to the sun. So tilting the angle of the solar collectors to keep it in a vertical lot of mathematical and automatic process is carried out around the globe. Our research uses the mathematical model for calculating tilting angle for the collector nodes starts from the longitude of 74.35 to 93.95, the latitude of 37.05 to 6.75 for collector nodes for India for 12 months of time. The results prove that each month the angle of the collectors changes with the latitude with the respective month. The optimums tilt angles for solar tracking and estimating of a mathematical model at the latitude range predicated as theta+25 for December, January. And teeta+15 for September and theta 15 for August the result confirmed that tilting angle increases with the increase in latitude.

Empirical formulas were employed in early studies to estimate the optimum tilt angles at different sites, which are only related to the local latitudes. In [1] the conclusion was given that the tilt angle can be calculated as (latitude ± 15). Later, the authors in [2] conducted a series of experiments and proposed a new formula which is (latitude ± 8) to derive the value of the tilt angle. For specific locations, according to coastal radiation data, PV panels should be installed with the tilt angle of 2.8 greater than the latitude [3]. However, the accuracy of these statistics is not guaranteed due to limitations of geographical conditions. Solar energy can be directly converted into electric power through PV panels, and the tilt angle of PV panel significantly affects the power output. Therefore, many types of research in the past decades focused on the Solar Powered Electrical Vehicle with tilt angle

Figure 2: Studies of India with Solar Radiation Energy

Table 1: Specifications of Solar Vehicle

Product(L*W*H)mm	13500*10400*9800
The radius of wheels in mm	2150
Batteries	48V, 7AH
Controller	350W, 48V
Brushless motor	350W, 48V
Mini ground clearance in mm	5300
Range	Power mode 10 Km/charge Economy mode 25 Km/charge

Algorithm optimization of the tilt angle to maximize PV generation. Generally, the optimal tilt angle varies with several conditions such as the utilization period, geographic latitude, climate, surroundings and other atmospheric factors, i.e. Dust and pollution [4–6]. Many recent types of research attempted to propose more accurate mathematical models of the optimum tilt angle, mainly considering the calculation of the maximum solar radiation incident on inclined panels. In [7], seven irradiance decomposition models for estimating global plane irradiance (GPI) from global horizontal irradiance (ghi) were evaluated for a region in southern Africa, along with comparisons among six transposition models.

Three Meteorological datasets were combined with Perez and haydavies models to compute the irradiance on tilted surfaces in [8], and the cooling effect of wind speed was considered to increase the accuracy of estimating the PV energy output. In [9] the best transposition model was to be found for Singapore's climatic conditions, and the maximum annual in-plane irradiation was obtained when surfaces were tilted eastward by employing the perez et al. Model. It is possible to collect 40% more solar energy by using a two-axis tracking system [10] and it is estimated that in sunny climates, a flat plate collector moved to face the sun twice a day can intercept nearly 95% of the energy collected using a fully automatic solar tracking system [10]it is generally known that in the northern hemisphere, the optimum collector orientation is south facing ($\gamma = 0$) and the optimum tilt depends upon the latitude and the day of the year. In winter months, the optimum tilt is greater (usually latitude angle + 15º), whilst in summer months, the optimum tilt is less (usually latitude angle – 1 5 º). There are many papers in the literature which make different recommendations for the optimum tilt, based only on latitude [11, 12]. In practice, the collector plate is usually oriented south facing and at a fixed tilt which is set to maximize the average energy collected over a year. Chiou and el-Naggar [13] gave a method to calculate the optimum tilt angle of an equator-facing collector in the heating seasons. Kern and Harris [11] calculated the optimum tilt angle for equator-facing collectors, based on only beam radiusatIon. El-Sayed [14] has carried out an analysis to determine the optimum tilt angle by considering the effects of latitude, number of glass covers, clearness index and solar reflectivity.

This paper examines the theoretical aspects of choosing a tilt angle for the solar flat-plate collectors used at NewDelhi and makes recommendations on how the collected energy can be increased by varying the tilt angle seasonally four times a year. A computer program is developed to simulate the collected energy as the tilt angle is varied. The instantaneous incident radiation, it, on a flat-plate collector surface with slope β is given as [15].

The fossil fuel such as petrol and diesel is very expensive material for extracting. The major problem is greenhouse effect caused due to this burning of fossil fuel where a large amount of CO_2 will be emitted which causes lots of problems. According to recent surveys, the fossil fuels are depleting at a fast rate where in and around 50 years the whole fossil fuel in the world must be completely depleted. Therefore it is the need of the time to make a new exploration of natural resources of energy and power among the natural resources available sunlight is the most promising one. A solar vehicle is an electric vehicle powered completely or significantly by direct solar energy. Usually, photovoltaic (PV) cells contained in solar panels convert the sun's energy directly into electric energy. The term "solar vehicle" usually implies that solar energy is used to power all or part of a vehicle's propulsion. Solar power may be also used to provide power for communications or controls or other auxiliary functions. Solar vehicles are not sold as practical day-to-day transportation devices at present but are primarily demonstration vehicles and engineering exercises, often sponsored by government agencies. However, indirectly solar-charged vehicles are widespread and solar boats are available commercially

OBJECTIVE

Design and implementation of the solar-powered electric vehicle which has low weight and aerodynamic design system in Indian road conditions.

MOTIVATION

Main disadvantages of solar energy are such that it is not a constant source of power and the amount of solar energy available keeps on varying throughout the day and at night time it is completely unavailable. So to power our vehicle during the absence of solar energy we designed an alternative method of obtaining the power to run the vehicle from the Electric supply. The attaching the whole structure of the vehicle and the control over the vehicle is difficult.

SYSTEM DEVELOPMENT

Block Diagram

The main components of the solar vehicle consist of:-

- Power supply
- Chassis
- Wheels
- Batteries
- Solar panels
- Motor
- Handle

- Brake

The above diagram gives us the perceptible idea of a system which constitutes of solar panels. The solar radiations incidents on solar panels, the photovoltaic cells it converts the solar energy into electrical energy. After that, we store the electrical energy into car batteries. The output of the solar panel is DC voltage. The regulator is used to regulate the voltage. So there is no variation in the output voltage. Now the output of the regulator is given to the input of the DC motor. DC motor is converted the electrical energy into mechanical (rotational) energy. This energy is used to rotate the front wheel. Chassis is used for the synchronization between backside two wheels. Steering is placed the upper side of the DC motor. Steering is used for the moving vehicle left or right. In the absence of solar energy, we charge the vehicle with the help of external electrical supply

HARDWARE DESIGN

Power Supply

The basic step in the designing of any system is to design the power supply required for that system. Hence we are giving power supply to the solar vehicle with the help of the solar panels and electrical current giving bye external device.

Wheels

Diameter is important. Large diameter wheels traverse bumps better than small diameter wheels. Larger wheel diameters will, however, increase car weight and also require a larger reduction ratio between the motor and drive wheel, possibly making the design and construction of the transmission more difficult. Remember, the track is constructed from sections and there will inevitably be some mismatch at joints. Very small wheels can tend to trip on these bumps. To reduce friction, wheels should run on ball bearings shielded to reduce dirt ingress, but not sealed. Seals add friction. A word of caution here, the small ball bearings normally used in this application have a low load rating. These are adequate for normal operation but a crash or improper handling during installation can apply loads high enough to permanently damage a bearing. Typically the damage takes the form of permanent deformation of the balls and races. That is, the balls have flats on them and the races have dents in them. The result of this damage is that the bearing then runs rough with significantly increased friction. Be especially careful to lubricate bearings with light oil. The urban myth that running bearings dry decreases friction is totally wrong as it is against all sound engineering practice and in any case tests have proven that bearings running dry and clean have about 250% more friction than lubricated bearings. Many cars have been constructed with wheels at around 40-50 mm in diameter and appeared to perform without problems

Various components of Solar Powered Electrical Vehicle.

Batteries

Batteries are used for the store the electrical charge. In this project, we add four batteries. The charging time of batteries depends upon the solar panel produced current and the battery total current. It is the ratio of the battery current to the solar plates current. The one battery having 48V, 7 Ah capacity. The total current of four batteries is 7Ah because the batteries are connected in series. In series, the current will remains same and voltage is increased. Therefore the charging time of batteries is,

Time for charging = Battery current in Ah/ Solar panel current

- **T**=7/1.46

- **T**=4.8Hr

Solar Panels

Maximum power is developed from a panel when light strikes it at right angles. This is virtually impossible to achieve on a model solar car, as the position of the Sun relative to the car changes as the car traverses the track. Shading even one element on a panel will drop the output significantly. Take care when mounting your panel to avoid shading and remember to keep the panel clean. Solar panel power output falls as the panel temperature increases so do not leave your panel laying around in the sun cooking. Some competitors will even cool their panels prior to racing. With panel power dropping by about 0.5% per degree C temperature rise, a 25 degree C temperature reduction results in a worthwhile power increase. Be cautious as the panel will heat quickly to quite high temperatures when placed in the sun (60 deg. C panel temperatures have been measured after ½ hour on a cloudless day of 20 deg C).

As we know,

P=V*I

For single plate:

2W=I*8.20

I=2/8.20

I=0.24 Amp

For all six plate:

P=V*I

12W=I*8.20

I=1.46 Amp

Total 6 plates, each plate is 2W. Therefore power becomes 12W.

Here,

P= Power of solar plates.

I= Current in solar plates.

V= Voltage of solar plates

The chassis should be as light as possible but must be strong enough to hold together during handling and running. It must also be stiff enough to hold everything in alignment and position (consider the possibility of rough handling & accidents). Take care that your chassis is not so stiff that the car tends to lift the drive wheel off the track as the car moves over undulations in the track as this has been observed on several occasions. Some form of suspension, or packing the drive wheel down lower than the other wheels may be required. It has been observed that, in general, cars with some flexibility have better track holding characteristics than stiff cars. 3 wheel cars will always have all wheels on the track. It is not mandatory that a separate chassis is used. A well designed and constructed body can perform the same functions as a separate chassis and this is how modern motor vehicles are designed and build.

Motor

The regulations allow the use of any motor or motors. Generally, permanent magnet brush type direct current (DC) motors are used as they are common, readily available and well suited to this application. Inexpensive motors can be used successfully to power a car but in general, their performance is inferior to the high-quality motors used in the most competitivers.

Controller

The controller is used for the increase or decreases the speed means it is used for speed controlling purpose.

Accelerator

Accelerator is used for the increase and decrees the speed of the vehicle. When the accelerator is fully anticlockwise the speed of the vehicle is maximum and vice versa.

Brake

It is used for the control of the vehicle. Brakes provide the stopping power of your bike. It refers to both the levers at the bars and the braking mechanism that stops the wheel from turning. There are many different options available depending on your bike and the type of riding you wish to do.

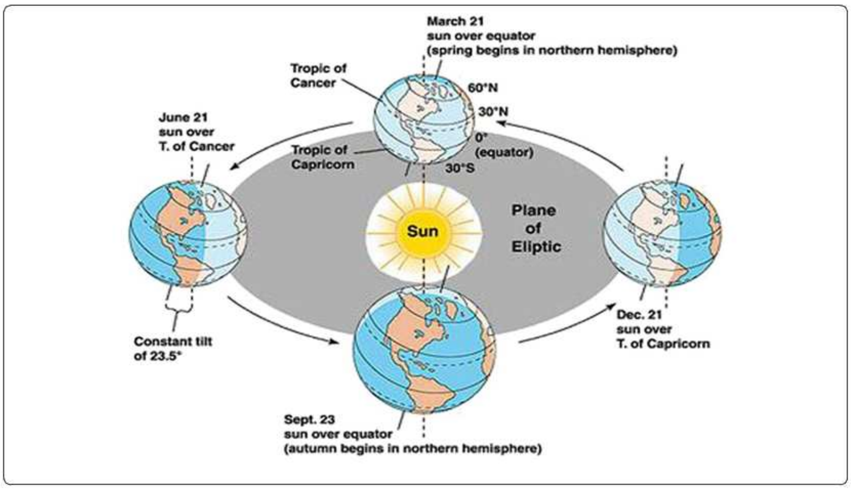

Figure 3: Earth Inclination Angle with the Sun

Mathematical Modeling of Solar Tilt Angle

The instantaneous incident radiation, IT, on a flat-plate collector surface with slope β is given as [10]:

IT = Ib T + Id T + Ir T (1)

Where IbT, Id T, and Ir T are the beam, diffuse and reflected instantaneous components of the solar radiation on a tilted surface. The diffuse, reflected and the beam components are given as [6]:

Id T=Id (1 + cos β) / 2 (2)

Ir T = ρI(1 – cos β) / 2 (3)

Ib T = Ibcos θ / cos z (4)

where Id, Ib and I are the instantaneous values of the diffuse, beam and global radiation on a horizontal surface and ρ is the solar reflectivity of the location.

The global radiation can also be written as:

$$I = Ib + Id \tag{5}$$

Therefore,

$$I = \rho\ (Ib + Id)\ (1 - \cos \beta) / 2 \tag{6}$$

Angle θ is the angle between an incident bean of flux and the normal to a plane surface and is given by [7]:

$$\cos \theta = \cos (\varphi - \beta)\cos\delta\cos\omega + \sin(\varphi - \beta)\sin \delta \tag{7}$$

where φ is the latitude,

δ is the declination angle

And ω is the angle from the local solar noon.

The declination angle is given as (8)

$\delta = 23.45 \sin [360(284 + n)/365]$(8) where n is the day number of the year (1 – 365).

Angle zn Equation (4) is the angle for a horizontal surface ($\beta = 0$) and using Equation (9)

$$\cos z = \cos \varphi \cos \delta \cos \omega = \sin \varphi \sin \delta \tag{9}$$

The calculation of the total radiation IT on a tilted surface can be carried out using the measured values of It and Id and the measured (or estimated) value of ρ.

$$\cos \theta = \sin \delta \sin \varphi \cos \beta - \sin \delta \cos \varphi \sin \beta \cos \gamma + \cos \delta \cos \varphi \cos \beta \cos \omega + \cos \delta \sin \varphi \sin \beta \cos \gamma \cos \omega + \cos \delta \sin \beta \sin \gamma \sin \omega$$

where φ is the latitude of the site,

β is the tilt angle of PV panel,

γ is the azimuth angle,

ω is the hour angle which shifts with the sun movement.

3. Software commutation process

The mathematical formula is converted intocomputer simulation to calculate monthly average tilt angle for the solar PV cells for south facing surface for a tilt angle of 0 to 90 degree.

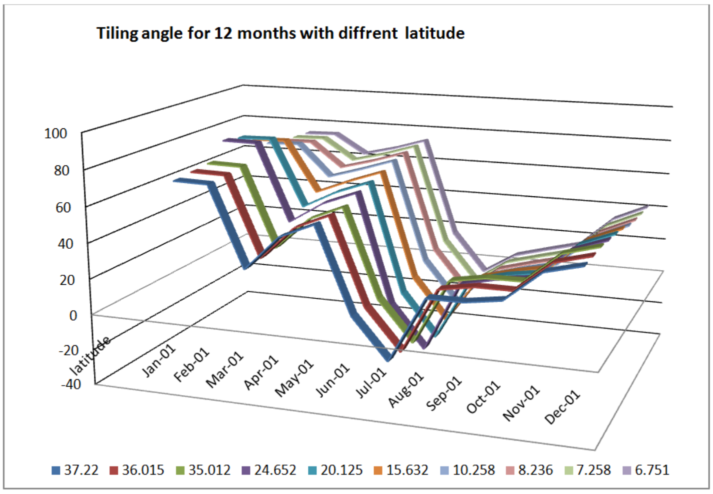

Figure 4: Tilt Angle of Different Latitude for JAN-DEC

Table 2: Tilt Angle for Solar Collecters

Latitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
37.07	76.32	75.82	32.11	51.05	59.20	12.86	9.34	26.15	26.15	29.04	45.25	50.15
36.02	77.37	76.87	33.17	51.45	59.53	11.88	10.38	25.46	28.75	28.71	45.04	50.15
35.01	78.36	77.86	34.17	51.84	59.85	10.95	11.37	24.81	28.20	28.38	44.82	50.13
24.65	87.84	87.54	44.52	56.34	63.64	2.03	21.00	17.77	22.25	24.56	41.77	48.86
20.13	86.15	86.58	49.04	58.64	65.59	3.62	20.02	14.59	19.48	22.60	39.96	47.64
15.63	81.91	82.39	53.53	61.14	67.74	7.61	15.3	11.39	16.58	20.43	37.83	45.99
10.26	76.62	77.12	58.89	64.52	70.69	12.57	10.53	7.52	12.86	17.46	34.80	43.38
8.24	74.62	75.11	60.91	65.92	71.93	14.45	8.52	6.05	11.35	16.22	33.50	42.19
7.26	73.64	74.14	61.89	66.63	72.56	15.36	7.55	5.34	10.60	15.58	32.83	41.58
6.75	73.14	73.64	62.39	67.00	72.90	15.84	7.05	4.97	10.21	15.24	32.47	41.24

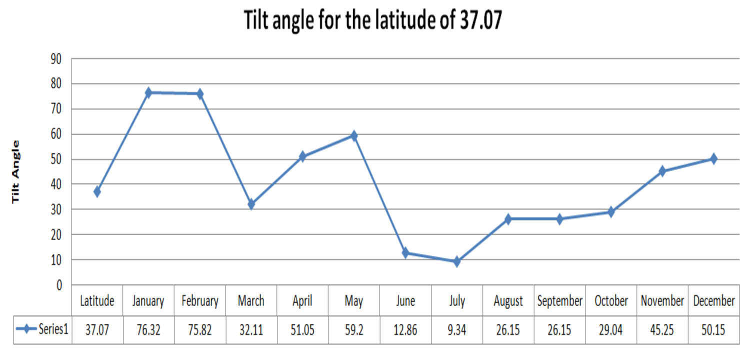

Figure 5: Tilt Angle for the Latitude of 37.07

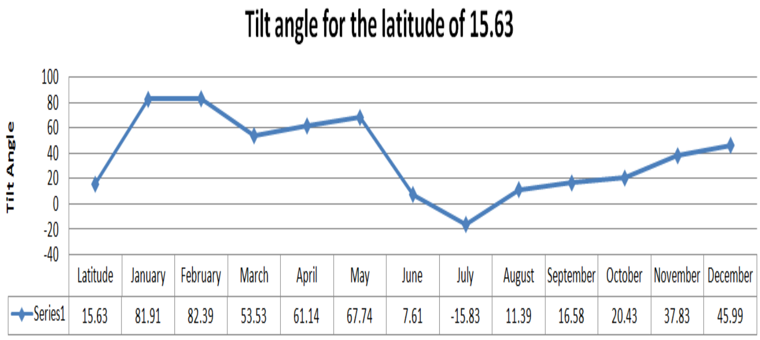

Figure 6: Tilt Angle for the Latitude of 15.6

Table 3: Solar Irradiation for Different Latitude with Perfect Tilt Angle

Latitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
37.07	2.418	2.407	2.816	3.159	5.513	6.695	6.615	5.689	6.131	5.425	4.777	3.011
36.02	3.342	3.120	2.559	4.648	6.119	6.633	6.403	5.926	6.099	6.308	3.591	2.973
35.01	2.190	2.041	2.395	3.343	4.588	6.072	5.366	4.538	4.736	4.510	3.724	2.054
24.65	5.460	6.764	6.985	6.405	6.611	4.591	2.669	2.843	5.393	6.770	6.227	5.522
20.13	6.119	6.812	6.562	6.634	6.638	4.161	2.482	2.619	4.491	5.994	6.402	6.231
15.63	6.783	7.153	6.275	5.797	6.358	4.246	3.272	3.391	4.411	5.011	6.322	6.793
10.26	5.554	6.288	5.845	5.157	5.802	5.893	5.397	5.795	5.689	3.819	3.326	4.484
8.24	5.901	6.565	6.216	5.445	5.910	5.966	5.469	5.935	6.128	4.303	3.414	4.491
7.26	3.768	4.893	4.312	4.540	3.254	3.261	3.169	3.271	3.387	3.369	3.240	2.580
6.75	4.825	5.815	5.102	5.323	4.081	3.968	3.897	4.006	4.031	3.617	3.853	3.475

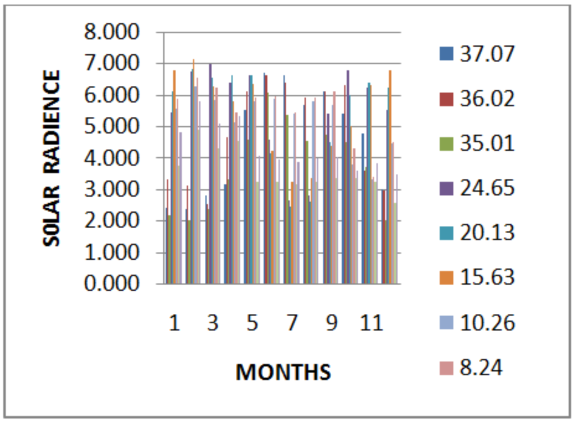

Figure 7: Graph of Solar Irradiation for Different Latitude with Perfect Tilt Angle

PERFORMANCE ANALYSIS

System Operation

The solar radiations incidents on solar panels, the photovoltaic cells it converts the solar energy into electrical energy. After that, we store the electrical energy into car batteries. The output of the solar panel is DC voltage. The regulator is used to regulate the voltage. So there is no variation in the output voltage. Now the output of the regulator is given to the input of the DC motor. DC motor is converted the electrical energy into mechanical (rotational) energy. This energy is used to rotate the front wheel. Chassis is used for the synchronization between backside two wheels. Steering is placed the upper side of the DC motor. Steering is used for the moving vehicle left or right. In the absence of solar energy, we charge the vehicle with the help of external electrical supply.

Justification

The past decade has seen a drastic rise in the popularity of renewable energy sources. The technology that directly transforms the sun rays into electricity is evidently one of the most commonly used alternative energies in the transportation markets. An idea of inventing the car which could be silent and low maintenance, would not pollute with harmful emissions and would not require costly fuel expenditures has been the dream of many engineers for a long period of time. Since the research into solar energy is ongoing an always in the stage of development, the car designers are challenged in marketing the solar cars look like normal cars. The solar-powered electric vehicle is very much beneficial in today’s world because in today’s world is passing through the revolutions. The world demands smaller, lighter & cheaper

setups. In the early days, solar cars looked more like flying saucers or space shifts rather than earthbound vehicles. In near future, it is expected that solar system can be adjusted to standard looking cars that we are all used to.

CONCLUSIONS

- Finally, we have designed optimal auto rickshaw have mileage 20 Km/hr and the weight capacity is 50-60 kg and the range is Power mode 10 Km/charge and Economy mode 25 Km/charge.
- In PV array works only part of the I-V characteristic near the working point maximum voltage and current. The photovoltaic system works most of the time with maximum efficiency. The behavior of the PV cell in electrical changes in the varies parameters like resistance, sun irradiation, temperature, and a parameter of the diode are the value considered as input and the I-V and P-V characteristics are considered to output. Increasing temperature yields decreasing power and voltage and increasing sun irradiation the current and voltage and also power will be increased. Parallel resistance, no significant effect or (little effect) on the I-V and P-V curve if a change of resistance has a very low effect on power.
- The analysis shows that solar rickshaw is a good solution for end to end connectivity (last mile connectivity).
- For the public transport system, the solar e-rickshaw is a partial green technology.
- The Solar Charging Station is another innovative concept and it provides a basic infrastructure for the electric vehicle.
- This mathematical method is than other software oriented method because its avoid use extra instruments for angle findings for collectors like thermal expanding liquids. However, that mathematical calculation is always will not be perfect with the atmospheric conditions from the research that we observe that angle varies with the months at a different latitude where the collectors are fitted.

Future Scope

- Terrestrial application of the rovers the NASA uses in space.
- Data collection in a hot, sun-rich area.
- Spread the world about the use of harnessing solar power.
- When the non-renewable energy is not available then we can use the same.
- A vehicle powered by the wind energy use wind turbines and valves which are placed in such a position that the turbines can start moving. The valves absorb wind which is needed to power the car. Alternator used to convert wind energy into electrical energy

Applications

- Eco-friendly greenhouse transport system.
- Data collection in a hot, sun-rich area.
- Auxiliary power used in the car for the ventilation.

- When the non-renewable energy is not available then we can use the same.
- Solar energy is used to supply power for satellites and spacecraft.
- Solar power thermal electric power plant.
- Solar heating system.
- Solar lighting.
- Renewable solar power system with regenerative fuel cell system.

Advantages

- Low cost.
- Extremely reliable.
- Low weight.
- Comfortable.
- High efficiency.
- No pollution (GREENHOUSE TECHNOLOGY).
- More speed.

RESULTS AND DISCUSSIONS

Predicted solar radiance with the calculated tilt angle and the actual radiation is compared. the result proves the increased irradiance of solar. Thetilt angle for whole of India from 37.07 to 6.05 latitude plotted as tabled. This mathematical method is than other software oriented method because the use of extra instruments for angle findings for collectors like thermal expanding liquids. However, that mathematical calculation is always will not be perfect with the atmospheric conditions. From the research that we observe that angle varies with the months at an different latitude where the collectors are fitted.

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